SAPC 3690
COPY 1 OF 2

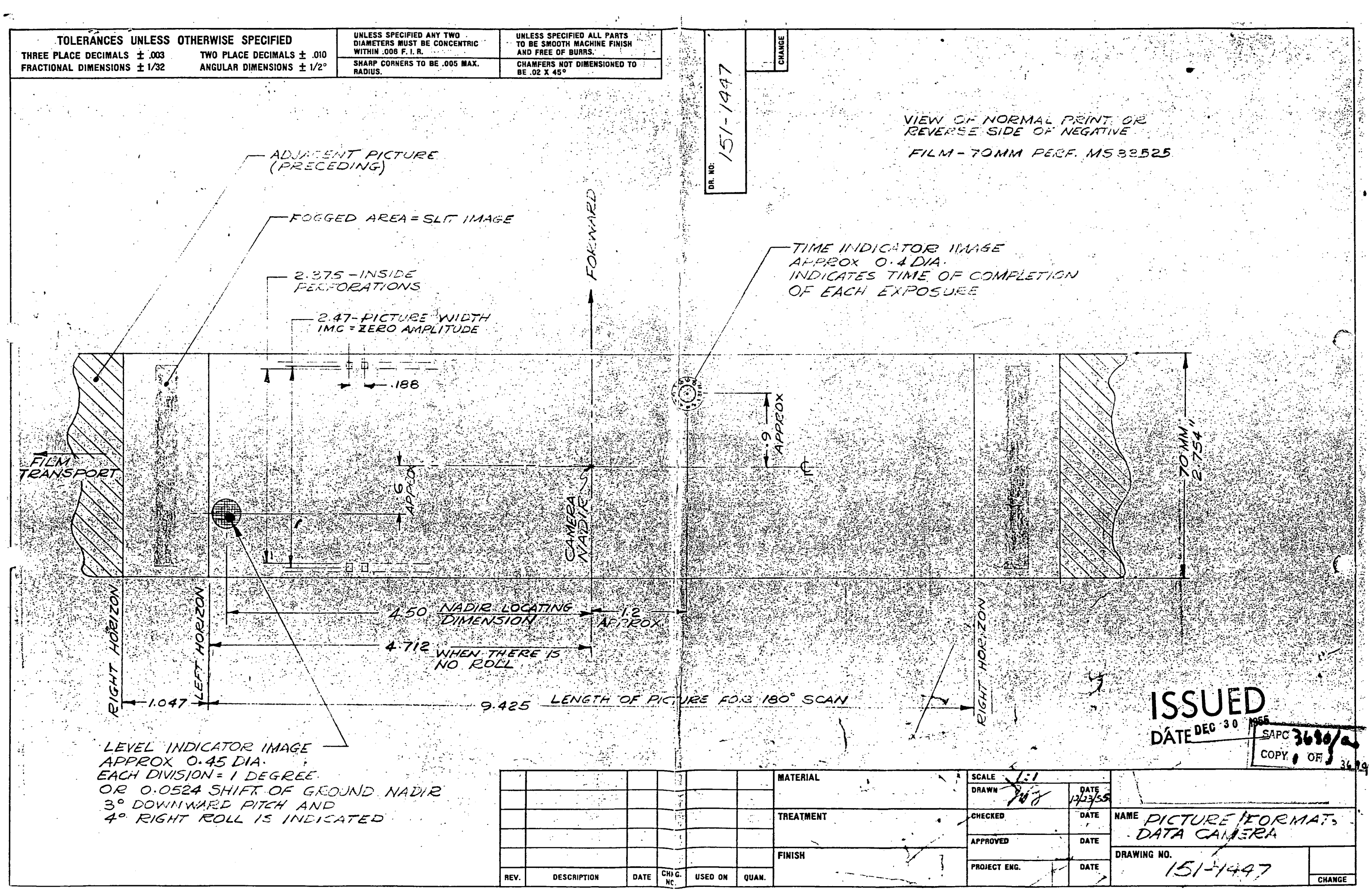
January 25, 1956

St. George:

Enclosed is a drawing of the format for 70 mm data camera. I am sending this to you so that you may forward it to the appropriate party for informational purposes.

TWM/dmg
enclosure - Dwg 151-1447

25X1


TOLERANCES UNLESS OTHERWISE SPECIFIED
THREE PLACE DECIMALS ± .003
TWO PLACE DECIMALS ± .010
FRACTIONAL DIMENSIONS ± 1/32
ANGULAR DIMENSIONS ± 1/2°
UNLESS SPECIFIED ANY TWO DIAMETERS MUST BE CONCENTRIC WITHIN .006 F. I. R.
SHARP CORNERS TO BE .005 MAX. RADIUS.
UNLESS SPECIFIED ALL PARTS TO BE SMOOTH MACHINE FINISH AND FREE OF BURRS.
CHAMFERS NOT DIMENSIONED TO BE .02 X 45°
DR. NO. 151-1447
CHANGE
VIEW OF NORMAL PRINT OR REVERSE SIDE OF NEGATIVE
FILM - 70MM PERF. MS 33525
ADJACENT PICTURE (PRECEDING)
FOGGED AREA = SLIT IMAGE
2.375 - INSIDE PERFORATIONS
2.47 - PICTURE WIDTH IMC = ZERO AMPLITUDE
FORWARD
TIME INDICATOR IMAGE APPROX 0.4 DIA. INDICATES TIME OF COMPLETION OF EACH EXPOSURE
.188
.9 APPROX
.6 APPROX
70MM 2.754"
FILM TRANSPORT
CAMERA NADIR
RIGHT HORIZON
LEFT HORIZON
4.50 NADIR LOCATING DIMENSION
1.2 APPROX
4.712 WHEN THERE IS NO ROLL
RIGHT HORIZON
1.047
9.425 LENGTH OF PICTURE FOR 180° SCAN
LEVEL INDICATOR IMAGE APPROX 0.45 DIA.
EACH DIVISION = 1 DEGREE
OR 0.0524 SHIFT OF GROUND NADIR
3° DOWNWARD PITCH AND
4° RIGHT ROLL IS INDICATED
ISSUED
DATE DEC 30 1955
SAPC 3630/a
COPY 1 OF 3
MATERIAL
TREATMENT
FINISH
SCALE 1:1
DRAWN
DATE 12/23/55
CHECKED
DATE
APPROVED
DATE
PROJECT ENG.
DATE
NAME PICTURE FORMAT, DATA CAMERA
DRAWING NO. 151-1447
CHANGE
REV.
DESCRIPTION
DATE
CHKG. NO.
USED ON
QUAN.

3005
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NAVIGATION DEVICE FOR AIRCRAFT

INTRODUCTION

The basic problem of determining position on the earth's surface by the observation of a single astronomical object reduces to one of measuring the altitude of the object above the true horizon and the azimuth of the object with respect to true North. If the object is near the North pole of the heavens, the effect of errors in azimuth on the determination of latitude is small but the effect of such errors on the longitude is very large. On the other hand, the observations of an object at a large distance from the pole yields results which are strongly affected in both latitude and longitude by errors of azimuth. Two nearly simultaneous objects, or two observations of the same object spaced in time are often solved in such a way as to remove the dependence of the solution on a knowledge of azimuth.

An object such as Polaris is ideal for the determination of latitude because errors of azimuth have no appreciable effect on the result. The latitude is directly the altitude of the pole above the true horizon. Only approximate azimuth is required for locating the star. Once it has been found, a knowledge of the Greenwich time permits a simple but very accurate determination of azimuth. No practical solution for longitude is available from observation of this star. The latitude problem reduces itself to measuring the altitude of the star above the true horizon and making a small correction for the fact that the star is not exactly at the pole, and the result is the latitude. This procedure works only in the northern hemisphere where Polaris is above the horizon. There is no such conveniently located star in the South. More unfortunately, there isn't a bright star close enough to the South pole to make this method even attractive since the azimuth corrections become large as the polar distances increase.

Having determined the latitude and the azimuth, the problem of obtaining longitude from a second body is greatly simplified. In fact, the simplest form of sun dial, once it has been properly oriented to the North and the gnomon set at the latitude angle, gives excellent local solar time and thus provides an accurate determination of longitude.

It, therefore, seems to me that the simplest form of the classical approach to the navigation problem under the conditions of rapid motion experienced in aircraft is one in which nearly simultaneous observations of Polaris, from which the pilot obtains azimuth and latitude, and the sun from which he may obtain longitude knowing latitude and azimuth.

The one non-astronomical problem associated with this determination is the accurate location of the true horizon. The ocean navigator uses the apparent horizon formed by the water surface, corrects for the height of his eye above the water, and for the horizontal refraction. While accelerations make the observations more difficult, they do not affect the accuracy of the horizon.

The aerial navigator on the other hand makes his altitude observations with reference to a bubble. These do not need to be corrected for eye height or for refraction but they are strongly affected by accelerations. It is the proposal here that the entire horizon, by optical means, be brought under the observation of the pilot. This circle could be photographed with respect to reference circles and the displacement of the horizon image measured on the photograph and used as a basis for correction. What seems a bit more attractive to me is to present the circle to the pilot's vision and let him fly the plane so as to center it in concentric circles. The accuracy required is something better than 1/10 degree but this should be no problem in straight and level flight since it is regularly accomplished with a gun sight in rather violent maneuvers. The removal of the need for a level correction is the first step toward a complete solution of the navigation problem without either mental correction on the part of the observer or computed corrections. The instrument that is described below carries out this philosophy by a series of successive approximations.

METHOD OF USE

While the design of this instrument is by no means complete, I visualize it to consist of a cylindrical assembly, perhaps 7" or 8" in diameter, 10" long, capped by a dome more than a hemisphere in shape, about 7" in diameter. The dome should project upward through the fuselage or canopy so that it sees as much of the horizon as is practical. The portion of the instrument which is inside the aircraft should be in such a position as to be visible to the pilot and accessible to his right hand. There will be two windows which he will be required to look through or at but they can be small; one about 2" in diameter and the other perhaps 2" x 1/2". In addition, there will be two counters reading latitude and longitude directly to 1/10 degree. Three knobs will project from the instrument. They will be, respectively, latitude, longitude and azimuth. The image of the horizon could be presented in the same instrument but it might be more practical to build it into the periscope or drift sight. By the flip of the switch, an image of the horizon appears in the periscope together with some concentric circles. The pilot will fly the aircraft so as to maintain the horizon concentric to these circles. The exact position of the horizon line with respect to any of the circles is unimportant, since we are only trying to maintain the level of the aircraft and not measure the dip.

Under conditions where the horizon is not uniform, for example, clouded layers at 20,000 feet to the north; ocean horizon in the west; high and rugged mountains to the south and a haze-bank of unknown altitude in the east, the pilot's eye could well integrate the affect of all these different surfaces and provide the information required to level the aircraft. When he is satisfied that the level is good, he pushes a button, perhaps located where the firing button for guns would normally be, and this activates the mechanism in the "navigator". Previous to this leveling operation, the pilot has put in his best knowledge of his latitude, longitude and azimuth. In the long thin window he sees two scales, a magnetic compass, and an azimuth scale which he has brought to true North according to his best knowledge of the magnetic declination. Before take off, the instrument has been set by three adjustments. The declination of the sun for the particular day has been set into the instrument, the clock has been wound and set to indicate the Greenwich hour angle of the sun, and a small prism has been rotated to such a position as to compensate for the displacement of Polaris from the North pole. This angle, like the declination of the sun, depends on the date and does not change significantly during any one day. The pilot's act of pushing the button has taken a picture. A sketch of what this picture might look like is included. Two images are superimposed on this picture. One is the image from a long focal length telescope showing Polaris, the other is an image of the sun taken through a second smaller optical system. If Polaris appears in the center at the crosslines, then the pilot knows two things immediately. His assumed latitude is correct and his introduced azimuth is correct. Under these conditions, the position of the sun with respect to its scale gives the longitude directly, and if his assumed longitude has also been correct, this image will appear in the center.

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On the other hand, if any of these assumed quantities are wrong, the following will be true: The vertical displacement of the star image gives the correction to the latitude and the right-left displacement gives the correction to the azimuth. This photograph is seen by projection in the round window of the instrument. Immediately after the picture is taken, it is developed and projected. The pilot looks at it, turns two dials, the latitude dial by the amount of the indicated correction, and the azimuth dial by the amount of its correction. He should check that the image of the sun is in the field for if it is not, his assumed longitude is wrong. If it is in the field, its position with respect to its scale will indicate the longitude rather closely but corrections for the errors in latitude and azimuth are required to give the correct longitude from this first exposure. These corrections are two in number. The one due to azimuth is given below.

Longitude = azimuth cos (latitude) cos (Local Hour Angle)

The error due to an incorrectly assumed latitude is as follows:

Longitude = – Latitude sin (Local Hour Angle)

It will be noted that all of this information is available from the picture but it requires a bit more mental arithmetic than we should ask the pilot to perform. I believe that he should proceed to make the corrections in the assumed latitude and azimuth and take a second picture by again flying level while he pushes the button. If then Polaris is within 1/10 degree or so of the center, the longitude indicated by the position of the sun's disc would be correct to the required 1/10 degree.

The proportions of the instrument have been so chosen as to permit errors of $\pm 5^{\circ}$ in all of the assumed quantities and still have the image of Polaris appear in the field. The five degrees is equivalent to a circle of 300 miles radius. The size of the corrections vary rather widely with position of the earth and time of day but in the worst case, that of low latitude (near the equator) and small hour angles of the sun (near local noon) the error in longitude is nearly equal to the error in azimuth running about 60 miles to the degree. In this case, however, the error in azimuth as indicated in the first photograph may be added directly to the observed longitude. Further, under this condition, the error due to an incorrectly assumed latitude is zero.

There is no error in the latitude produced by an error in azimuth provided the aircraft is level at the time of the picture. Thus, the observed deviation of Polaris in the vertical direction may always be added directly to the assumed latitude. The information which is available from the appearance of the first picture is the correct latitude, a good shot at the correct longitude, and an accurate correction to the azimuth. It is my suggestion that the pilot now put in the correct latitude, put in the correct azimuth, put in his present good shot at the longitude, fly level and take another picture. This picture should now give him latitude and longitude, both correct to 1/10 degree (about 6 miles) and azimuth with nearly the same accuracy. I am sure I will hear someone suggest that we record the magnetic deviation at this point of the proceedings, and if this is really desired for intelligence purposes, I suspect this feature could be easily added.

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THE INSTRUMENT

No complete designs of the instrument are available, as I indicated before, but a drawing showing the basic optical arrangement of the head portion of it is enclosed. The central portion which carries the small telescope through which the sun is imaged, the longitude scale and its associated clock drive, and the prism for correcting for the declination Polaris, are all mounted on a horizontal axis which points East and West. In fact, the adjustment for azimuth is that which brings this axis into its true East-West position. This portion of the instrument then is the counter part of the telescope of an astronomical transient. It carries two telescopes, one pointed along its polar axis, looking at Polaris, and the other rotating about the polar axis looking at the sun. In this second telescope is a scale driven by the clock to show the local hour angle of the sun at Greenwich. The position of the sun's image on this scale reads the local longitude.

The East-West axis is mounted on bearings permitting the elevation angle to be set to the latitude. An optical system brings the images from the sun and Polaris through the center of one of these bearings downward to a base plate and through an azimuth bearing. The arrangement of the optical system is indicated in one of the sketches. This permits the photographic material to be stored and processed and projected in a stationery position with respect to the observer.

I hope that some of these ideas will be attractive to you for I feel that we have not requested too much of the pilot, and yet have provided a piece of mechanism which is about as simple a one as can be made to solve the problem.

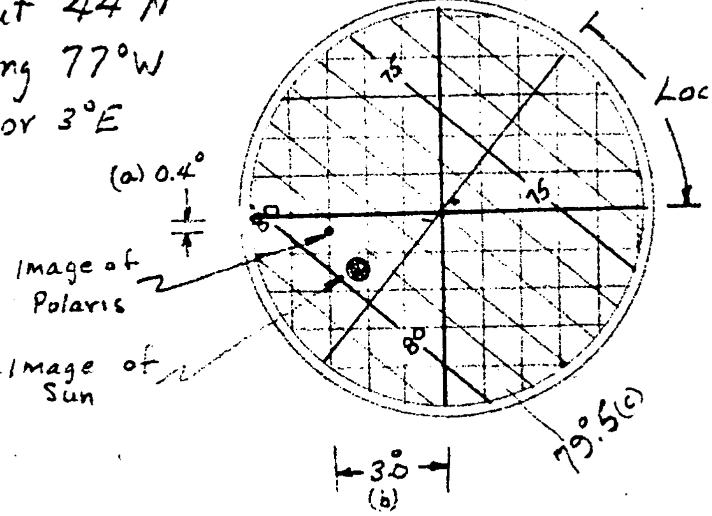
RMS/dmg
October 19, 1955

SAPC 3005-A
COPY 2 of 2

Correct Latitude 43.6 N
" Longitude 78.4 W
Sun LHA 48°.6 W GHA 127°.0 W
GST 0828P
GMT 0830P
(June 20, 1945 Tables at Hand)

First picture

Assumed Lat 44°N
" Long 77°W
Azimuth error 3°E



a) error in Latitude = -0.4° ∴ True Latitude is 44 - 0.4 = 43°.6

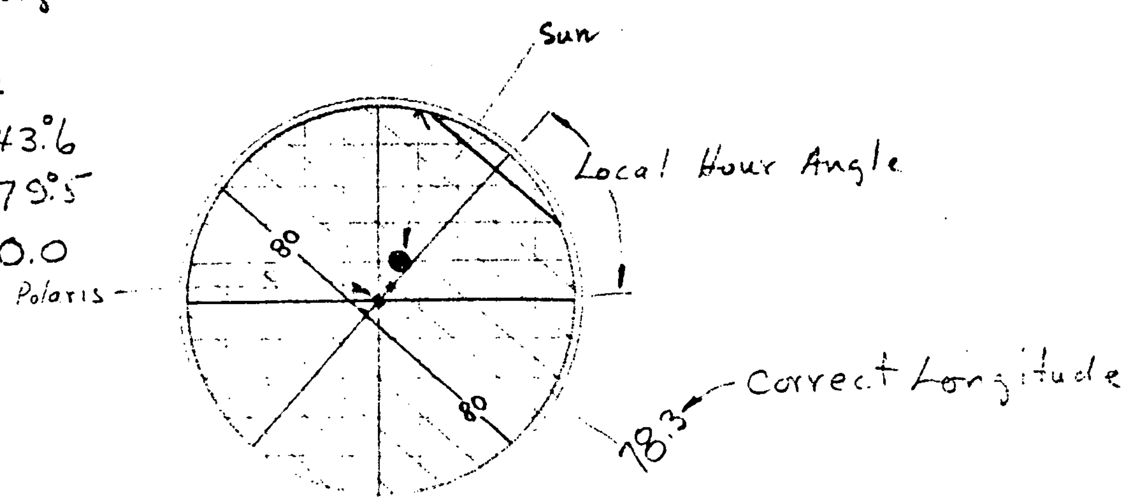
(b) error in azimuth = -3°.0 δLong = -3.0 × 0.7 × 0.7 = -1.5
= δAz (Cos Lat) (Cos LHA)

-δLong = -0.4 × 0.7 = +.3
= δLat (Sin LHA)

(c) Longitude observed 79.5
True Longitude 79.5 - 1.5 + 0.3 = 78.3

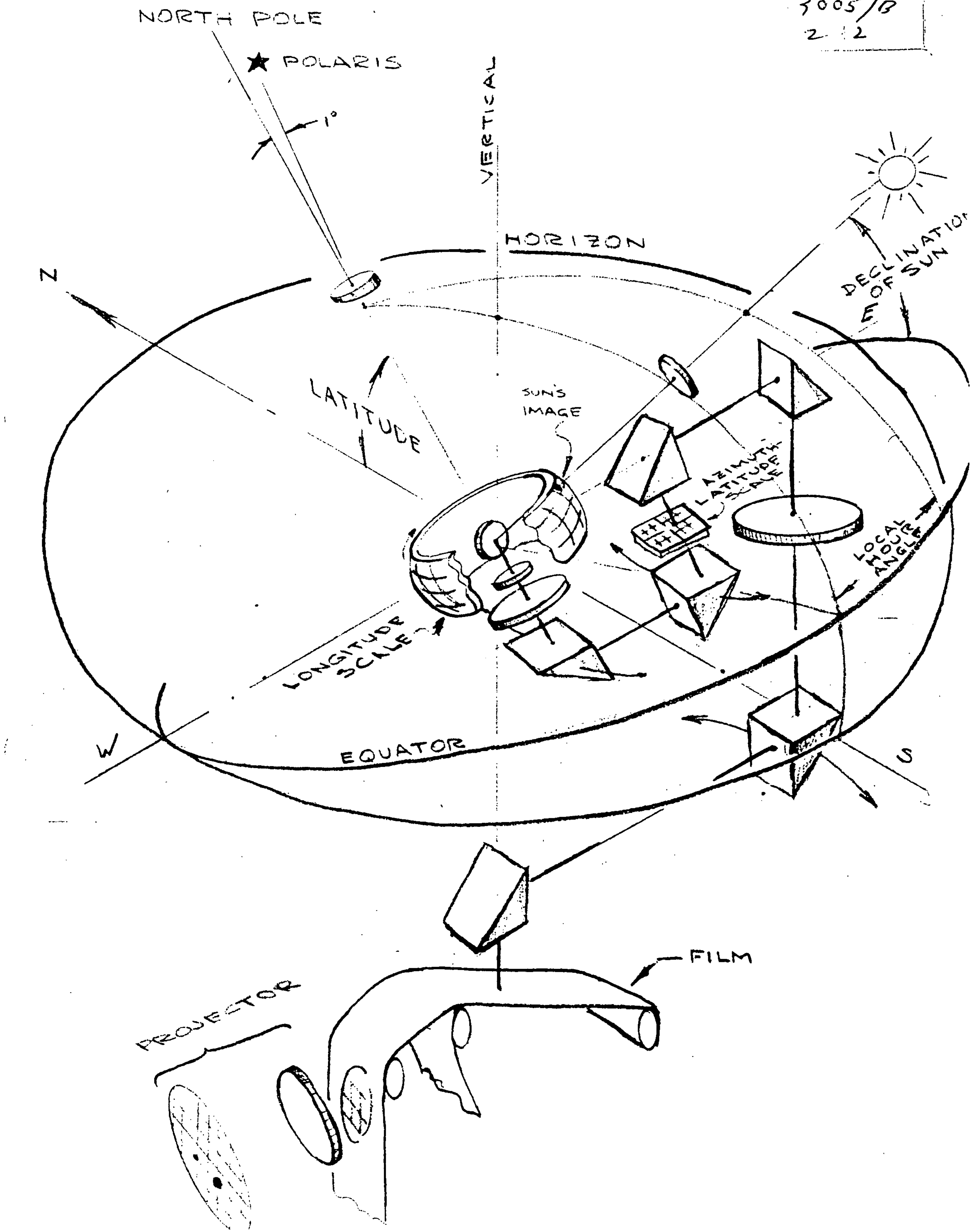
Second Picture

Assumed Lat 43°.6
Assumed Long 79°.5
Azimuth error 0.0

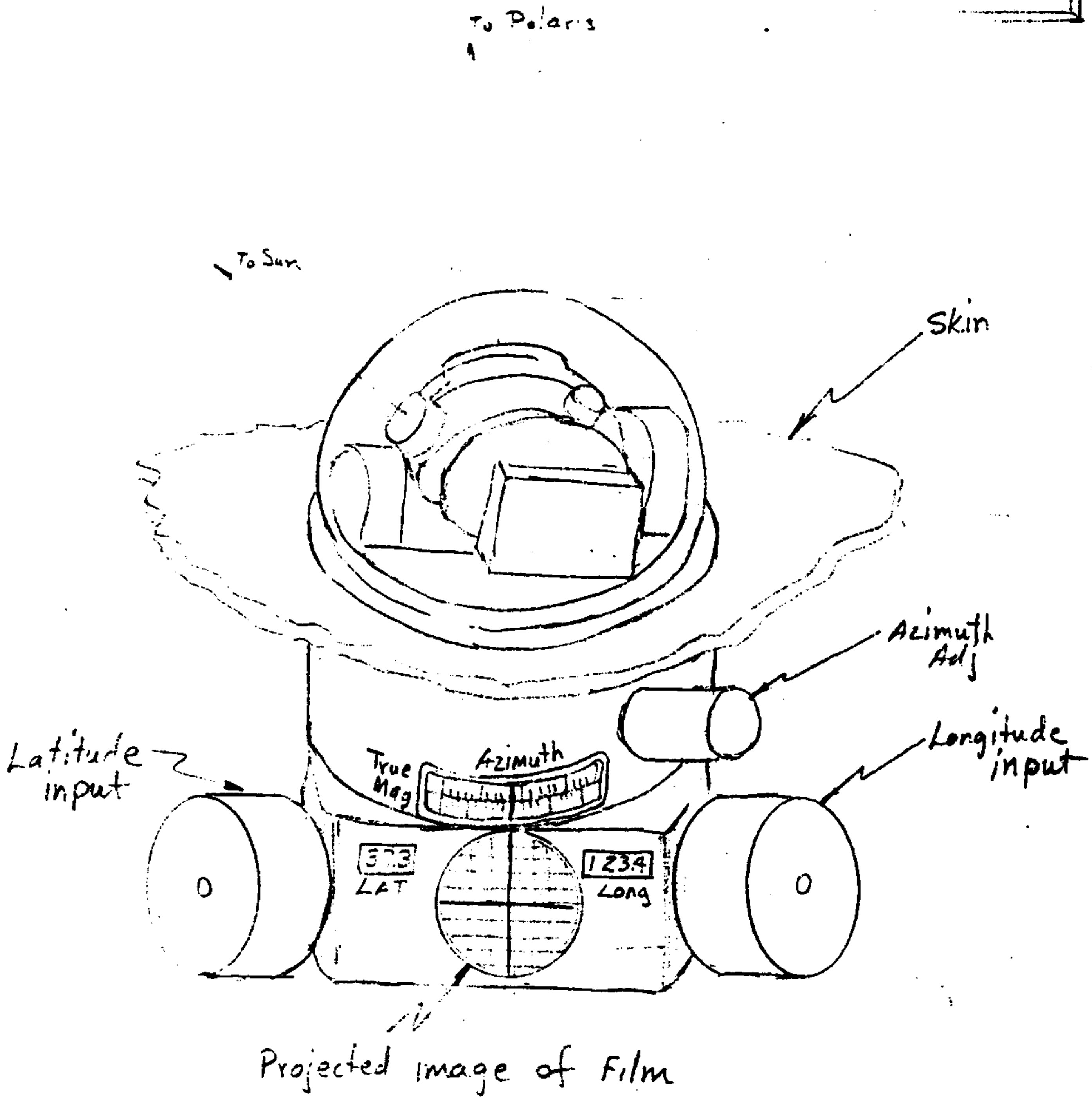


10/19/55

3005/B
2 2


NORTH POLE
POLARIS
1°
VERTICAL
HORIZON
DECLINATION OF SUN
N
E
LATITUDE
SUN'S IMAGE
AZIMUTH LATITUDE SCALE
LOCAL HOUR ANGLE
LONGITUDE SCALE
W
EQUATOR
S
FILM
PROJECTOR

3005/c
2 2



Note - input knobs could be all on right side or on bottom.

- Portion below Skin does not turn - can be installed in any position but should be vertical in normal flight.

RNS
10/19/55